Warning Concerning Copyright Restrictions

The Copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyright material. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction not be "used for any purposes other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

CHAPTER ONE

Introduction and Historical Overview

The Study of Memory
Memory Metaphors
Memory Methodology
Memory Terminology
Understanding the Study of Memory
A Short History of Research on Memory
Antiquity and the Middle Ages
The Beginning of Modern Psychology
British Empiricism and Continental Nativism
Scientific Psychology
Hermann Ebbinghaus
Experiment: The Forgetting Function
Research After Ebbinghaus
Chapter Summary and Further Reading

> *There seems something more speakingly incomprehensible in the powers, the failures, the inequalities of memory, than in any other of our intelligences. The memory is sometimes so retentive, so serviceable, so obedient—at others, so bewildered and so weak—and at others again, so tyrannic, so beyond control! We are to be sure a miracle every way—but our powers of recollecting and of forgetting, do seem peculiarly past finding out.*
>
> —Jane Austen

The Study of Memory

If we had no memory, in the broadest sense of the term, we would not be able to function. Memory is essential for all activities. When riding a bicycle, we rely on memory to provide the appropriate processes to keep our balance, keep the pedals turning, and navigate down the path. When reading, we rely on memory to provide knowledge about word definitions, facts, and concepts. We also need memory to keep track of the flow of ideas, why one sentence or paragraph of text follows another. When chatting with friends, we rely on memory to provide information about details of our own lives, what we did last week, or what happened at the ball game. When listening, we rely on memory to retain, however briefly, parts of the auditory signal so that it can be processed. When creating an image of what a room would look like with its furniture rearranged, we rely on memory to provide the structural descriptions that allow us to construct a mental picture. A person's identity and definition of self rely solely on memory, both for what the person has done, thought, and believed and for what others have said. Memory plays such an important and ever-present role that it is often overlooked. The only time most people pay attention to their memory is when it fails.

The study of memory seeks to understand these and many other aspects of memory. Like most people, researchers look for situations in which memory fails. It is by comparing situations where memory is successful to ones where it fails that psychologists have discovered and documented the principles by which human memory operates. Although the research is not so far progressed that we can predict each individual's behavior in every particular situation, the accumulated knowledge does allow us to predict general memory performance in a wide range of situations. The purpose of this book is to introduce you to this accumulated knowledge, to illustrate the process of designing and conducting diagnostic research, and to present a survey of the resultant theories that summarize and explain the data and make predictions about performance in novel situations. As you will see, our powers of remembering and forgetting can indeed be found out.

Memory Metaphors

One of the central questions researchers must address when developing a theory or model is how best to think of memory. When most people think about memory—psychologists included—they typically conceive of a place where information is stored. As Roediger (1980) has noted, this spatial metaphor has dominated the study of memory: "We speak of *storing* memories, of *searching* for and *locating* them. We *organize* our thoughts; we *look* for memories that have been *lost*, and if we are fortunate, we *find* them" (p. 232).

In addition, these spatial metaphors have typically represented the newest or most important technology available. For example, Aristotle, in his *De memoria et reminiscentia*, compared memory to a wax tablet, with forming a memory like making a seal on wax with a signet ring. The durability of the memory depended on the age and temperament of the person, just as the durability of an impression depends on the age and malleability of the wax.

> Some men in the presence of considerable stimulus have no memory. . . . With them the design makes no impression because they are worn down like old walls in buildings, or because of the hardness of that which is to receive the impression. For this reason the very young and the old have poor memories; they are in a state of flux, the young because of their growth, the old because of their decay. For a similar reason neither the very quick nor the very slow appear to have good memories; the former are moister than they should be, and the latter harder; with the former the picture has no permanence, with the latter it makes no impression. (Aristotle, quoted in Yates, 1966, p. 33)

Plato compared memory to an aviary, whereas Augustine compared memory to a cave—both spatial objects. Vives compared memory to a body, claiming that both need regular exercise or they become lazy, sluggish, and inert. Francis Bacon compared the act of recollection to hunting a deer; if one cuts down the available space in which the deer can roam, the hunting is easier. Descartes, in *De homine*, used an analogy to the water-powered automata in the French royal gardens to describe simple reflexes and incorporated them into his conception of how the mind and body interact (Herrnstein & Boring, 1965). John Locke thought of memory as an empty cabinet. By the early 20th century, memory was being compared to a gramophone, an updating of the wax tablet metaphor but with a more precise description of various problems (Pear, 1922).

By the mid-1950s, descriptions and theories of memory were borrowing much from the telephone system and from information theory (Broadbent, 1958), only to be eclipsed by the digital computer metaphor, with the interaction of hardware and software (Feigenbaum & Simon, 1962). This metaphor led directly to what is referred to as the dual-store or modal model of memory, with separate short- and long-term stores (see Chapter 3).

Perhaps the most unusual—but still spatial—metaphor compared memory to a cow's digestive system and the passage of information through the memory system to the passage of food through the various stomachs and orifices of a cow (Hintzman, 1974a). Hintzman noted that the metaphor is invoked by phrases such as *food for thought, digesting information,* and *ruminating*. The process of forgetting was not explicitly described, but it was thought to be the reverse of "incremental learning: namely, excremental forgetting" (Hintzman, 1974a, p. 85).

In all these views, memory is a place in which memories are stored, a position called the *structural view*. Consider the following alternative to the structural view:

> Memories, like perceptions and eventually sensations, have no separate existences. The memory of what you saw yesterday has no more existence until revived than the pain you felt in your arm before it was pinched. . . . In short, for the experiencing individual, memories do not exist before they are revived or recalled. Memories are not like filed letters stored in cabinets or unhung paintings in the basement of a museum. Rather, they are like melodies realized by striking the keys on a piano. Memories are no more stored in the brain than melodies in the keys of the piano. (Wechsler, 1963, pp. 150–151)

This second view, called the *proceduralist view,* emphasizes the processes that create and re-create the memory, rather than the structure or location in which a memory might be stored (Crowder, 1993a). This idea also has long history, having been developed earlier by Bain (1855) and Hebb (1949).

Obviously, at some level, memories are stored somewhere; as we experience more and more, we remember more and more, and so structures must be important. Equally obvious, however, is that there is no one place that a memory is put. If, for example, one cell were responsible for the memory of my grandmother and that cell died (as cells do all the time), all memory for my grandmother would be permanently lost. Although neither the structuralist nor the proceduralist view can explain all memory phenomena, the field as a whole has come to emphasize process over structure. Even 25 years ago, Kintsch (1977) concluded that "many psychologists today are no longer satisfied with the box metaphor that underlies the earlier models. . . . Instead, a more dynamic conception of the memory system is evolving, with an emphasis on differential processes rather than on separate boxes" (p. 225).

A third view takes the position that discovering and enumerating general principles of memory provides an appropriate and scientifically sound mode of explanation (Neath & Surprenant, 2003a; Watkins, 2001). This approach follows in the tradition of the *functionalists* (Angell, 1907; Carr, 1930), who were concerned with answering the question "What is the function or purpose of the behavioral act?" As one example, consider the *cue overload principle* (Watkins, 1979). This principle states that the ability of a cue to elicit a particular memory can be reduced if additional items become associated with the same cue; in other words, the cue becomes overloaded and no longer functions effectively. A variety of experimental findings can be explained as instances of this general principle, and invoking the principle reduces the number of phenomena that need explanation.

No single view of human memory can explain all the phenomena of interest. Within each type of account are many different, sometimes incompatible, theories. One important goal of this book is to introduce you to these various theories of memory and to illustrate how these theories are developed and evaluated.

Memory Methodology

One problem with studying memory is that everyone has one and has experience with how it works. When a cognitive psychologist reports the results of a study, a common reaction is to exclaim, "My grandmother could've told me that!" However, the psychologist conducts experiments to determine, as objectively as possible, how memory works. An experimental psychologist uses an established set of procedures that may or may not confirm your grandmother's own experience but that do produce reliable and replicable results. As a rule, experimental psychologists are particularly wary of any unsubstantiated claim, and this may be why it seems that a reference is cited for almost every statement made (Neath & Surprenant, 2003b, Chap. 1).

The primary reason for this reliance on experimentation is that although many conventional beliefs about memory are correct, many are not. For example, many people believe that photographic memory exists, and the majority of college students believe that hypnosis will recover repressed memories (Klatzky, 1984); neither appears to be the case (see Chapters 11 and 12, respectively). A properly conducted experiment—or more usually, a series of experiments—will provide evidence that either confirms or disconfirms such statements. Citing a research study ensures that theories are based on scientifically gathered data rather than on general, untested speculations. Although many of the results may indeed be things that your grandmother knows, there is an important difference between basing conclusions on sound scientific research and untested folk wisdom.

A working definition of *memory* might be that it is the ability to use or revive information that was previously encoded or processed. Memory is never directly observed, and we need not even be aware of its influence; rather, its existence is inferred from some particular behavior or some change in level of performance. Therefore, the type of evidence needed to support the claim of memory versus no memory for a particular event requires special attention.

Another goal of this text is to give you an appreciation for experimental design. Almost every chapter has a description of the procedures necessary to conduct a classic memory study in one of two ways. The first type requires no unusual or expensive equipment and all the necessary stimuli are included in the Appendix. The second type requires only a computer, a networked connection to the Internet, and a recent Web browser. Having conducted an experiment, you will be in a better position to appreciate the arguments that surround its theoretical interpretation.

When people first become acquainted with how experiments are designed and conducted, a common reaction is to wonder whether such artificial-looking procedures can say anything interesting about memory in ordinary, everyday situations. Many researchers have similar concerns, and a debate over ecological validity regularly resurfaces. *Ecological validity* in this context refers to the extent to which an experiment in a controlled laboratory setting reflects what happens in ordinary, uncontrolled settings, usually dubbed "the real world." This recurring debate began again most recently when Ulric Neisser (1978) wrote, "If X is an interesting or socially significant aspect of memory, then psychologists have hardly ever studied X" (p. 4). He further claimed that most experimental findings were obvious or trivial and, most important, they failed to generalize outside the laboratory. According to this view, research in the tradition of Bartlett (1932), whom we will discuss in Chapter 12, has fostered more important findings than has research in the tradition of Ebbinghaus (1885), whom we discuss later in this chapter. For example, Bartlett used sentences and prose passages in his research rather than the nonsense syllables that Ebbinghaus used, and Bartlett examined memory in social settings whereas Ebbinghaus tested only himself.

Two rebuttals to Neisser's critique were offered. Roediger (1990a) pointed out that Neisser's claim is based on a rather limited review of the experimental literature. Many people Neisser cited as prime contributors to the "thundering silence" on practical issues actually spent a large portion of their careers studying practical aspects of memory. A good example is John McGeoch (see Crowder, 1992b, for a brief biography). Although best known for his interference theory of forgetting (see Chapter 6) and his 1942 textbook, McGeoch also contributed substantially to what would now be called applied memory research. In addition, Neisser overlooked the many laboratory findings that do generalize to the real world. For example, research that used artificial stimuli (nonsense syllables) in an artificial task (paired-associate learning) in an artificial setting (the laboratory) consistently found that distributed rather than massed practice produces better memory: If you allot 2 hours for practice, your memory will be better if you separate the practice into several smaller chunks (say, four half-hour blocks) than if you mass all the practice into one 2-hour block. These results have consistently generalized to the "real world": Information is retained longer if it is learned in several shorter sessions than in one longer session (for example, see Herrmann, Weingartner, Searleman, & McEvoy, 1992; Singh, Mishra, Bendapudi, & Linville, 1994). In fact, changing your study habits from massed study to distributed study is perhaps the easiest and most effective way to enhance your retention of information (see Chapter 15). It should not really be surprising that results do generalize from the laboratory to real life. As McGeoch and Irion (1952) put it, "Life in the laboratory is just as 'real' as life may be anywhere else" (p. 8).

An earlier statement by Moore (1910, p. 116) nicely captures the relation between laboratory research and behavior in "real world" conditions:

> It is very seldom, if at all, possible to reproduce in the laboratory the exact conditions of real life. Most of our experiments can only approximate more or less closely the actual occurrences in the external world. This is not, however, an insurmountable difficulty for the experimental psychology. We have not one mind for the laboratory and another for the world. The same mental processes that take place in the world are observed in the laboratory, but under different conditions. The change in conditions is in the direction of greater simplification. The mental process of the laboratory is, as it were, a purified product and its true properties can therefore be more easily determined.

As an interesting side note, the work of Ebbinghaus, done in the "ecologically invalid" way, has consistently been replicated, whereas many of Bartlett's best-known findings, done in a more "ecologically valid" way, have not. For example, the general shape of the forgetting function is the same as Ebbinghaus reported regardless of whether the stimuli are words or sentences (Slamecka & McElree, 1983) or television shows (Squire, 1989). Other examples are the difference between massed and distributed rehearsal cited

Table 1.1 A two-by-two array of approaches to scientific research

		Ecological Validity of Method	
		Low	*High*
Generalizability	*Low*	Cell 1	Cell 2
of results	*High*	Cell 3	Cell 4

SOURCE: Based on Banaji & Crowder (1989).

earlier, and the effects of the time of day on memory (Petros, Beckwith, & Anderson, 1990). In contrast to this tradition of successful replication are some of Bartlett's best-known findings. Bartlett had his subjects read a Native American folk tale called the "War of the Ghosts." Because his subjects were British, they had almost no knowledge of Native American customs, traditions, and symbolism, and the story was particularly difficult for them to understand and recall. Bartlett reported that over successive recall attempts, more and more distortions were introduced. Although this result is presented in most texts, there are actually no successful replications of this result (see Gauld & Stephenson, 1967; Roediger, Wheeler, & Rajaram, 1993; Wheeler & Roediger, 1992). Of course, many of Bartlett's other studies on memory are easy to replicate, but these show patterns of results similar to those reported by Ebbinghaus.

A different critique of Neisser's thesis was offered by Banaji and Crowder (1989). Their main point was that experiments (in any area) can be classified into one of four categories. The generalizability of the results—the degree to which the results apply widely across a broad range of situations—can be either high or low, and the ecological validity of the method can be either high or low. These four possibilities are shown in Table 1.1.

Banaji and Crowder noted that Cell 4, which represents high ecological validity and high generalizability of results, represents the ideal; Cell 1, which represents contrived, artificial methods with no generalizable findings, is the least desirable situation. Banaji and Crowder disagreed with Neisser in that they opted for Cell 3 (low ecological validity but high generalizability of results) as a better compromise than Cell 2 (high ecological validity but low generalizability of results). As support for their contention, they cited many studies with apparently low ecological validity of methods (such as displaying letters and words for 1/20th of a second) that have had an enormous impact on important everyday behaviors (such as reading).

Unfortunately, many experiments that fall within Cells 1 and 2 (low generalizability of results) have been conducted and published. These studies contribute little to our knowledge of memory, and they can even hinder progress if methodological flaws have led to incorrect conclusions. Part of your job, as a student of memory, is to learn how to distinguish between those studies in Cells 1 and 2 and those in Cells 3 and 4.

Memory Terminology

In 1972, Underwood posed the following question to researchers studying human behavior: "Are we overloading memory?" Part of the problem, as he saw it, was the large number of different types of memory. If anything, the number of terms has proliferated since his article. Although Underwood was referring to overloading the subject's memory with

Table 1.2 Theory-neutral and theory-specific terms for various kinds of memory.

Type of Information	*Theory-Neutral Term*	*Theory-Specific Term(s)*
Sensations	Sensory memory	Iconic memory Echoic memory Precategorical acoustic store (PAS)
Information to be retained only briefly	Immediate memory	Short-term store Short-term memory Primary memory Working memory
Information to be retained indefinitely	Generic memory	Long-term store Long-term memory Secondary memory
Personal history	Autobiographical memory	Episodic memory
Knowledge	Generic memory	Semantic memory

Terms in the far right column entail specific assumptions, especially about the division of memory, whereas terms in the middle column are intended to be neutral.

all the different types of processing that could occur, he could also have been referring to the student of memory, who must try to retain the important distinctions among the many different proposed systems and subsystems. Table 1.2 lists some of the memory terms that will be encountered frequently.

In this text, when referring to a specific theory, we will use the terms listed in the far right column of Table 1.2. When referring to the same type of memory but without wishing to invoke a particular theory, we will use the terms listed in the middle column. The theory-specific terms carry with them particular assumptions, whereas the theory-neutral terms (as much as possible) do not. For example, the terms *episodic* and *semantic* usually imply separate memory systems along the lines proposed by Tulving (1972, 1983). In contrast, the terms *autobiographical memory* and *generic memory* refer to remembering the same kind of information as episodic and semantic memory, respectively, but are neutral on whether the systems are separate and on the presumed underlying processes. Similarly, *working memory* is usually taken as implying Baddeley's (1986) proposal, whereas *immediate memory* is the neutral equivalent, implying neither separate memory stores nor a monistic view. The terms *implicit* and *explicit memory* are not included in the table; the definitions for these terms are rather complex and will be provided in Chapter 7.

Understanding the Study of Memory

As you read through this text, keep in mind that understanding memory involves an awareness of the relationships among research, data, and theory. The experiments that are provided (both paper-and-pencil and the Web-based CogLab experiments) will give you an appreciation for experimental design. Having conducted an experiment, you will be in a better position to appreciate the arguments that surround its theoretical interpretation. You should also be able to distinguish between experiments whose results are generalizable and can be applied widely across a broad range of situations and those whose results are limited to particular situations (see Table 1.1). You should not be surprised if the results confirm something you already know, but you should also be willing to change your mind when the results disconfirm something you believe. Finally, you should see how theories are developed and evaluated. In a sense, every theory of memory is wrong. The process of conducting research, collecting data, and evaluating theories is designed to continually refine theories.

A Short History of Research on Memory

Hermann Ebbinghaus is quoted as saying that "psychology has a long past, but only a short history" (Boring, 1950, p. ix). What he meant was that although inquiries into the nature of memory began centuries ago, the early researchers lacked an appropriate set of rules, methods, and procedures for studying memory, and as a result the scientific study of memory is barely over 100 years old. Researchers did not begin to build a sound body of scientific knowledge until after they had abandoned *introspection* as the main research method.

Many early researchers believed that, just as people can be trained to observe external events accurately (judges at gymnastics or diving competitions, for example), so could people be trained to observe their internal cognitive events. Introspectionists were trained to "observe" their own mental functioning and to make repeated observations before coming to any conclusions. The main problem with introspection, as Karl Marbe (1869–1953), a leading researcher at Würzburg, quickly found out, was that similar observers performing the same act often gave very different descriptions. In one of Marbe's experiments, subjects were asked to judge which of two objects was heavier; although his subjects were quite accurate at identifying the heavier object, they could not agree on the process whereby they made this decision. (Marbe's disenchantment with introspection precipitated his change from experimental to applied psychology, where he developed aptitude tests for business and studied accident proneness with an eye to prevention; see Zusne, 1975.) As a method of inquiry, introspection has had a "dismal record of failure" in psychology (Bower & Clapper, 1989, p. 245). Although the earliest philosophers and researchers did gain many valuable insights through introspection, it should be noted that they made numerous errors as well.

Antiquity and the Middle Ages

Many ancient cultures had gods or goddesses associated specifically with memory. In Egypt in 4000 BCE, Thoth was the god of learning, memory, and wisdom; in Greece in 1000 BCE, Mnemosyne (from whom we get terms such as *mnemonic* and *mnemonist*), mother of the muses, was the goddess of memory (Herrmann & Chaffin, 1988). Although there were undoubtedly many works on how to improve memory, the earliest surviving example dates from about 400 BCE. This fragment, known as the *Dialexeis* (Yates, 1966, pp. 29–30), suggests that the three most important factors in remembering are paying attention, rehearsing, and using a formal mnemonic device, the *method of loci* (see Chapter 15).

The first real memory theorists were Plato (427–347 BCE) and Aristotle (384–322 BCE). Plato believed that all essential truths are stored in memory and that learning is simply the process of recollecting these truths. He offered three metaphors for memory. First, he likened memory to impressions formed on a wax tablet: A person might have a more or less retentive memory depending on the age of the wax, the hardness of the wax, the depth of the impression, and so forth. Second, he compared knowledge to birds in an aviary, with each different species of bird being a different piece of knowledge. A particular bird might be in the aviary but off in a distant part and not immediately accessible. Third, he likened memory to the recording of experience by a scribe, and therefore subject to the whims of the scribe: "When the inscribing feeling writes truly, then true opinion and true propositions are formed within us in consequence of its work—but when the scribe within us writes falsely, the result is false" (Herrmann & Chaffin, 1988, p. 55).

Most of Aristotle's writing on memory is found in a brief essay called *De Memoria et Reminiscentia* ("On Memory and Reminiscences"). The title reflects a distinction that Plato draws in *Philebus*: Memory is the power of retention, whereas *recollection* (or reminiscence) is the power of recall. Humans are said to have both, but other animals lack recollection. Recollection is based on associations, and an *association* is simply the connection of two mental events (ideas, thoughts, beliefs, memories). Philosophers and psychologists have identified three laws of association within the works of Aristotle: Events tend to be associated when they occur close together in time or space (the law of contiguity), when they are similar (the law of similarity), and when they contrast with each other (the law of contrast).

In the Roman world, the emphasis was on practical aspects of memory rather than on theory. Both Cicero (106–43 BCE) and Quintillian (40–96 CE) emphasized the role that memory played in oratory: Cicero emphasized the importance of order as an aid, and Quintillian emphasized exercise, both mental and physical (Burnham, 1888). An anonymous work written around 86 BCE, known as *Ad Herennium*, is the most famous pragmatic work on memory from that period (Yates, 1966) and was the basis for much of the work of subsequent scholars.

The next early memory theorist was Augustine (354–430 CE). He identified two kinds of memory, sense memory and intellectual memory (Burnham, 1888). Sense memory preserves and reproduces images of objects, including sounds, odors, and touch. Intellectual memory is concerned with knowledge, including literature, science, and philosophy. He also noted the possibility of memory illusions, such as when "we fancy we remember as though we had done or seen it, what we never did or saw at all" (Burnham, 1888, p. 61). Augustine agreed with earlier scholars such as Plotinus (205–270 CE) that memory is not a simple, passive process but rather a complex series of actions that can affect the accuracy and the nature of the memory. This idea is reflected in one of Augustine's major concerns, retrieval. He compared memory to a cave in which were stored not the original events but images of the events. Whenever we attempt to recall something, we are limited by the associations of ideas. Augustine also mentioned one of the many paradoxes of memory: "We have not entirely forgotten anything if we can remember that we have forgotten it" (Herrmann & Chaffin, 1988, p. 119).

Relatively little survives from the Middle Ages, and much of the work on memory in the Renaissance concerns practical questions and mnemonic techniques (see Carruthers, 1990; Yates, 1966). Thomas Aquinas (1224–1274) generally followed the views of Aristotle; his main contribution was bringing the works of Aristotle to a wider audience, rather than adding anything new to his views on memory. Until this point, relatively little emphasis was placed on empirical testing of ideas. Most medieval scholars were more concerned with metaphysics and its relation to theology than with accumulating empirically based knowledge. A major change in attitudes is reflected in the works of Juan Luis Vives and Francis Bacon.

The Beginning of Modern Psychology

Juan Luis Vives (1492–1540), a Spanish humanist who studied in Paris and taught for a while at Corpus Christi College, Oxford, is often regarded as one of the great *empiricists* of the Renaissance. His central focus was on practical uses of knowledge, and he is well known for his many works on education. In his main writing on psychology, *De anima et vita libri tres* ("Three Books on the Soul and Life"), published in 1538, Vives called for greater attention to observation and experimentation and less reliance on ancient authorities. He discussed the association of ideas, following Aristotle's and Augustine's formulations, and discussed memory at length, including sections on a law of forgetfulness and on mnemonics. He identified three causes of forgetting: "either because the very picture in memory is erased or destroyed directly; or it is smeared and broken up; or because it escapes our searching" (Diamond, 1974, p. 256). Vives suggested writing down whatever one wanted to remember (Burnham, 1888), thus going against the strictures of Plato, who warned that writing down information "will create forgetfulness in the learners' souls, because they will not use their memories; they will trust to the external written characters and not remember of themselves" (Herrmann & Chaffin, 1988, p. 38). Vives also believed, however, that "if memory is not exercised, it grows dull, becoming slower each day, more sluggish and inert" (Diamond, 1974, p. 256).

Francis Bacon (1561–1626), too, emphasized the practical value of empirical discoveries in contrast to the results of metaphysical speculation and introspection, and his approach and ideas influenced many other prominent British thinkers. He believed that the three great powers were memory, fancy, and reason. He offered many practical insights into improving memory that have since been demonstrated as effective, such as associating the event with something concrete, studying before sleeping to reduce interference, processing information in several different ways rather than simply repeating it in rote fashion, and reducing the size of the search set. This last suggestion was accomplished by means of a "prenotion":

> By Prenotion I mean a kind of cutting off of infinity of search. For when a man desires to recall anything into his memory, if he have no prenotion or perception of that he seeks, he seeks and strives and beats about hither and thither as if in infinite space. But if he have some prenotion, this infinity is at once cut off, and the memory ranges in a narrower compass; like the hunting of a deer within an enclosure. (Bacon, quoted in Robertson, 1905, p. 168)

Bacon is also well known for his four Idols—preconceptions or *biases* that prevent or hinder the discovery of the real truth. The Idols of the Tribe are the generally agreed-upon ways of thinking; the Idols of the Den are biases created by a person's environment or education; the Idols of the Market Place are misconceptions based on loose use of vocabulary; and the Idols of the Theater are the blind acceptance of older ideas from tradition or authority. Despite his prominent role in establishing respect for the scientific method, Bacon did not think very highly of mathematics (Watson, 1968).

British Empiricism and Continental Nativism

Thomas Hobbes (1588–1679) was the first unqualified reductionist of modern times and is generally considered the first in the line of British empiricists. Recognition of his influence was delayed, however, because he was suspected of being an atheist. He served as a secretary to Bacon for a short period and was undoubtedly influenced by Bacon's ideas. Hobbes thought that memory and imagination are decaying sensations and that all of cognition is based on sensation. He argued that qualities are not properties of the object but of the perceiver: A box is not red; rather, the perceiver has the sensation of the box's being red (Watson, 1968). Sensations lead to simple ideas, and various combinations of simple ideas lead to more complex ideas. The importance of this line of reasoning is that it implies that the mind can be analyzed mechanistically, that the study of the mind can be made scientific. This belief that ideas arise from sensations, and hence from experience, also makes Hobbes an empiricist and thus in opposition to René Descartes (1596–1650).

Descartes has been called the first great psychologist of the modern era, although not the first modern psychologist. The primary reason for the designation "great" is that he attempted, for the first time since Aristotle, to create an entirely new system of thought. The basis of his system was doubt, the first principle of which was the famous *cogito, ergo sum:*

> I resolved that everything that ever entered into my mind was no more true than the illusions of my dreams. But immediately afterwards I noticed that whilst I thus wished to think all things false, it was absolutely essential that the "I" who thought this should be somewhat, and remarking that this truth "I think, therefore I am" was so certain and so assured that all the most extravagant suppositions brought forward by the sceptics were incapable of shaking it, I came to the conclusion that I could receive it without scruple as the first principle of the Philosophy for which I was seeking. (Descartes, quoted in Watson, 1968, p. 152)

The essence of man, for Descartes, was a mind, a "thing which thinks." The mind is contrasted with the body, and this separating of mind and body into two different aspects came to be known as *Cartesian dualism*. The mind and body can interact (Descartes localized the point of interaction as the pineal gland), but the mind can also act independently, as when it considers innate ideas. Whereas Hobbes concluded that the mind can be understood in mechanistic terms, Descartes argued that it cannot; only the body is amenable to such understanding. Whereas Hobbes believed in the accumulation of knowledge through sensations and experience, Descartes held that the most important ideas are innate. Innate ideas comprise the set of universal truths, and they are innate because they arise from consciousness alone and not from objects in the world. External objects may remind us of ideas, but ideas do not come to us from sensation (Watson, 1968).

Bacon's strong stance on using the experimental method for discovering knowledge was the basis for much of the work of John Locke (1632–1704). Locke is often mistakenly called the founder of associationism, but it was not until the fourth edition of his *Essay Concerning Human Understanding* (published in 1700) that he used the phrase "association of ideas" (Diamond, 1974; Watson, 1968). His entire philosophy, therefore, was formed without the need for the associationist ideas, and he mentions neither Hobbes nor Aristotle. Locke's importance comes more deservedly from his empirical approach and his conception of the mind as a tabula rasa (clean slate) or "the yet empty cabinet" (Watson, 1968, p. 184). This idea, present in Aristotle's work, claims that experience rather than innate or inborn factors is of most importance. Locke went even further, suggesting that when something is not currently being contemplated, it no longer exists:

> But our ideas being nothing but actual perceptions in the mind, which cease to be anything when there is no perception of them, this laying up of our ideas in the repository of the memory signifies no more but this, that the mind has a power in many cases to revive perceptions which it has once had. . . . And in this sense it is that our ideas are said to be in our memories, when indeed they are actually nowhere. (quoted in Burnham, 1888, pp. 70–71)

Locke did much to refine introspection and to set bounds on what could and could not be understood about human nature with his empirical method. Also, following Hobbes, he thought of ideas as comprising elements that could be studied and analyzed.

Gottfried Wilhelm Leibniz (1646–1716) not only rejected Locke's empiricism but also disagreed with the notion that ideas had no existence when not being contemplated. He argued that if nothing remained when one ceased to think about a certain idea, it would not be possible to recollect the idea at a later time. Instead, Leibniz argued that traces of ideas remain even when they are not being thought of, although they are unconscious.

The empiricism of Locke prevailed in Britain, however. David Hartley (1705–1757), who also believed that the mind is blank at birth and that sensations give rise to ideas, systematized the views of the British empiricists and associationists. For Hartley, memory is "that faculty by which traces of sensations and ideas recur or are recalled in the same order and proportion, accurately or nearly, as they were once actually presented" (Burnham, 1888, p. 83). He distinguished between "true" memories, or recollections, and illusions of memory, or reveries: "All men are sometimes at a loss to know whether clusters of ideas that strike the fancy strongly, and succeed each other readily and immediately, be recollections or mere reveries. And the more they agitate the matter in the mind, the more does the reverie appear like a recollection" (Burnham, 1888, p. 84).

David Hume's (1711–1776) approach was to combine the experimental approach of Isaac Newton with Bacon's and Locke's study of the human mind, the ultimate goal being an experimental science of the mind. Indeed, the subtitle of Hume's *Treatise of Human Nature* is *An Attempt to Introduce the Experimental Method of Reasoning into Moral Subjects*. Hume noted that "the chief exercise of the memory is not to preserve the simple ideas, but their order and position" (Herrmann & Chaffin, 1988, p. 173). He also rediscovered two of Aristotle's principles of association—similarity and contiguity—but emphasized that his own third principle, cause and effect, was the most important. Hume recognized that associations are not automatic, and he used an analogy with gravitation to suggest the character of an association: "Here is a kind of Attraction, which in the mental world will be found to have as extraordinary effects as in the natural, and to shew itself in as many and as various forms" (Herrnstein & Boring, 1965, p. 348).

Immanuel Kant (1724–1804) distinguished three kinds of memorizing. The mechanical *(mechanisch)* method, which involves only frequent, literal repetition; the method of clever devices *(ingeniös)*, which involves forming associations between items; and the method of reflection *(judiciös)*, the best kind, which involves classification (Burnham, 1888). Kant has also been cited as a forerunner of connectionism (Van de Vijver, 1990). His *Kritik der reinen Vernunft* ("Critique of Pure Reason") attacked the empiricism of Hume; Kant went so far as to say that "it was the warning voice of David Hume that first, years ago, roused me from dogmatic slumbers" (Herrnstein & Boring, 1965, p. 586). In trying to refute empiricism, Kant argued that humans are born with certain innate properties, and this nativistic approach contributed a highly influential philosophical background for psychological schools such as the Gestalt movement in perception. The conflicts between Locke and Descartes are echoed in the opposition between Hume and Kant, and, later, that between Helmholtz and Hering (Herrnstein & Boring, 1965).

James Mill (1773–1836), in his *Analysis of the Phenomena of the Human Mind*, published in 1829, presents a thoroughly associationist view of memory but with several important insights. "In memory there is not only the idea of the thing remembered; there is also the idea of my having seen it. Now these two—1, the idea of the thing, 2, the idea of my having seen it—combined, make up, it will not be doubted, the whole of that state of consciousness which we call memory." The "idea of my having seen it" is also made up of two components, "the idea of my present self, the remembering self, and the idea of my past self, the remembered or witnessing self" (Burnham, 1888, p. 241).

Mill's son, John Stuart Mill (1806–1873), disagreed with his father's view of an infinite compounding of associations. Rather, he introduced the term *mental chemistry* to indicate that in combining simple elements, something new is created. Just as the properties of water are different from the properties of hydrogen and oxygen, the properties of a complex element may be different from those of the root elements. Mill thus anticipated Wundt and the Gestalt psychologists. Because of this view, Mill advocated studying complex ideas empirically rather than relying on observations of simpler elements.

Marie François Pierre Gonthier de Biran (1766–1824) was a French philosopher who took the name Maine de Biran, from an estate named Le Maine that belonged to his father. A member of Louis XVI's royal guards, he was injured defending the king in 1789 at Versailles. On the subject of memory, his important work is *Influence de l'habitude sur la faculté de penser* ("Influence of Habit on the Faculty of Thinking"), first published—without his name attached—in 1802 (Copleston, 1985). Although in his early works Maine de Biran followed such thinkers as Condillac and Bonnet, he later criticized and moved away from the empiricist school and became more of a Platonist (Copleston, 1985). He was careful to distinguish three types of memory systems: mechanical memory, which is concerned with motor tasks and operates largely at a nonconscious level; sensitive (or sensory) memory, which is concerned with feelings, affect, and fleeting sensations; and representative memory, which is concerned with conscious recollection of ideas and events (Schacter & Tulving, 1994).

Through Jean Gaspard Félix Ravaisson-Mollien (1813–1900), Maine de Biran's thought influenced the French philosopher Henri Bergson (1859–1941) (Copleston, 1985). Although best known for his work on topics other than memory—especially his *L'Évolution créatrice* ("Creative Evolution") published in 1907—Bergson gave an extended treatment to the idea of fundamentally different kinds of memory in *Matière et mémoire* ("Matter and Memory"), published in 1896. Like Maine de Biran, Bergson distinguished between two different memory systems. First, there is "a closed system of automatic movements which succeed one another in the same order and occupy the same time" (Copleston, 1985, p. 190). This form is similar to walking—a bodily habit—and is the type of memory that animals have, such as that possessed by a parrot taught to recite a passage of a poem. The second type is "pure memory," which represents and records "all the events of our daily life" (Copleston, 1985, p. 190). Because memory records everything, the function of the brain is to inhibit the majority of memories so that only those relevant or related to ongoing thought or action are recalled to consciousness. Bergson also argued that the brain is not a storehouse of memories but rather functions more as a telephone exchange. The neurological mechanisms permit various movements but do not themselves store memory (Copleston, 1985).

Alexander Bain (1818–1903) marks a transition. He belonged to the outgoing British associationist school early in his career but moved closer to the emerging German scientific psychology toward the end of the century (Zusne, 1975). He is noted for his attempts to connect psychology and physiology and, in particular, for his doctrine that "the renewed feeling occupies the very same parts and in the same manner as the original feeling" (Burnham, 1888, p. 243), a forerunner of the current proceduralist view of memory.

For example, the recollection of language, according to this view, is suppressed articulation. Bain was also the founder of the influential British journal *Mind* in 1876.

Ernst Heinrich Weber (1795–1878) had a medical degree rather than a doctorate in philosophy, but his experiments to determine the smallest detectable difference between two weights set the groundwork for scientific psychology. Although he found that the absolute magnitude of the difference varied depending on the size of the weights, he noted that the difference had a constant relationship to the weight: For an increment in a stimulus to be just noticeably different, the size of the increment had to be a certain proportion of the stimulus. This formulation, known as *Weber's Law*, might have gone unnoticed had it not been for Fechner (Diamond, 1974).

Scientific Psychology

Gustav Theodor Fechner (1801–1887) was the first scientific psychologist. Although he had a medical degree, his first interest was physics. Combining his interests in physics and philosophy, he initiated the field of *psychophysics*. He believed that the mind and body were aspects of the same unity (in contrast to Cartesian dualism). According to Fechner, it was on the morning of October 22, 1850, while still in bed, that he realized how to connect the body and the mind (Watson, 1968). The key, as he wrote ten years later in his *Elemente der Psychophysik* ("Elements of Psychophysics"), published in Leipzig in 1860, was finding the quantitative relation between a mental sensation and the physical stimulus:

> Just as, in order to measure space, we need a physical yardstick which is contained in space, so, in order to measure the psychic, we will need something physical which underlies it. But insofar as we cannot directly observe the psychophysical activity which does directly underlie it, the stimulus which evokes that activity, and with which it waxes and wanes in regular fashion, will be able to serve in place of the yardstick. (Diamond, 1974, p. 685)

Based on Weber's Law, *Fechner's Law* held that sensation (S) is directly proportional to the logarithm of the magnitude of the physical stimulus (P) multiplied by a constant, k:

$$S = k \log P \tag{1.1}$$

This formulation of psychophysics directly inspired Hermann Ebbinghaus to apply similar methods to the study of a higher mental process, memory. It is interesting that Ebbinghaus worked outside of the influence of Wundt, the giant of 19th-century psychology. Wilhelm Wundt (1832–1920) offered the first formal academic course in psychology, in 1867 at the University of Heidelberg, and founded the first psychology laboratory, at the University of Leipzig in 1875 or 1879 (depending on the criteria). Watson (1968) suggests that the latter date is notable only for the appearance of the first student to do publishable research.

The scientific study of memory, then, did not begin until the latter part of the 19th century and had as its roots Aristotle's associationism, the philosophical orientation of the British empiricists, and the precision of Fechner's emerging psychophysics.

Hermann Ebbinghaus

Hermann Ebbinghaus (1850–1909), generally identified as the first major scientific researcher of memory, received his doctoral degree in philosophy at Bonn in 1873 after serving in the army during the Franco-Prussian war. Although his dissertation concerned

Hartmann's philosophy of the unconscious, Ebbinghaus also had an interest in history and philology (the study of literature and of relevant disciplines such as linguistics, language, and speech). After completing his dissertation, he spent seven years traveling around Europe and Britain. During this time, he came upon a copy of Fechner's *Elemente der Psychophysik* at a secondhand bookshop in Paris and became acquainted with and influenced by the empiricist tradition in Britain (Boring, 1950).

Ebbinghaus's contribution to the study of memory, published in 1885, was called *Über das Gedächtnis: Untersuchungen zur experimentellen Psychologie* ("Memory: A Contribution to Experimental Psychology"). In it, he combined the techniques that Fechner had applied to the study of sensation with the topic of memory, long an important consideration of the British associationists. Although he is generally noted for being his only subject and for inventing nonsense syllables as his stimuli, these factors are neither problematic nor particularly important. Rather, Ebbinghaus's far more significant and lasting contribution was that he was the first experimental psychologist, outside of psychophysicists, who understood and used the concepts of (1) measurement error, (2) distributions of observations around a mean, and (3) the importance of evaluating differences between two conditions in light of error associated with the respective means (Crowder, 1976). He is also well known for his forgetting function, which will be described later.

As befits the first scientific investigator of memory, Ebbinghaus reported what is perhaps the first true experiment on memory: He outlined two possible theories, derived a testable prediction that could distinguish between the two possibilities, and then conducted the experiment to evaluate the hypothesis. Indeed, the basic idea that came out of this research still has currency and serves as the basis for Johnson's (1991) distinctiveness model of serial learning.

The idea of an association between items had been pervasive in philosophy for hundreds of years. However, there was still uncertainty about whether there existed only direct associations, or whether there were also remote associations (see Figure 1.1).

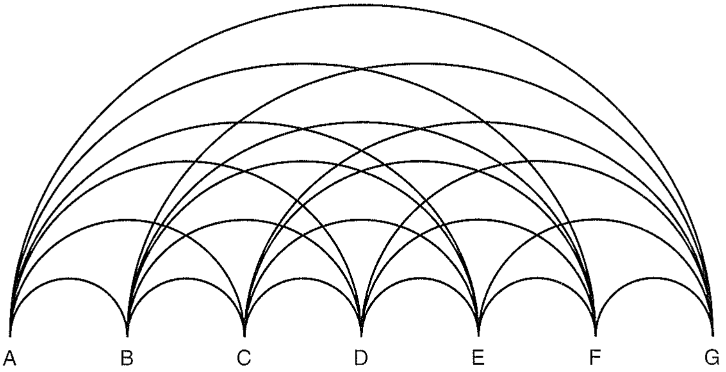

Figure 1.1 An illustration of the possible associations among seven items in a list. According to Ebbinghaus, the first item, A, can be associated with item B through a direct association, and with items C, D, E, F, and G through remote associations. The less direct the association, the weaker the link.

Experiment *The Forgetting Function*

Purpose: To demonstrate the classic forgetting function using the method of savings

Subjects: Thirty subjects are recommended. Ten should be assigned to the 1-hour group, ten to the 1-day group, and ten to the 1-week group.

Materials: Table A in the Appendix lists 24 nonsense syllables with approximately equal association values. Create a list of 13 nonsense syllables by randomly selecting the syllables from the table. Write each syllable in large, clear form on a notecard. Each subject should get a different random ordering of items.

Design: Because each subject experiences only one condition, delay is a between-subjects factor.

Procedure: Inform the subjects that in this experiment they will be asked to learn a list of nonsense syllables. Show the subject the list of syllables at a rate of approximately 1 syllable every 2 seconds. Then, ask the subjects to repeat the list. Record the subject's responses. Then show the subject the same list again, and ask the subject to repeat the list. Keep doing this until the subject can recall the list in order without making an error. Most subjects will require several trials before they recall the list. Keep track of how many trials are required to learn the list. Have the subjects in the 1-hour group return after 1 hour, the subjects in the 1-day group return after 1 day, and the subjects in the 1-week group return after 1 week. Repeat the procedure, being careful to ensure that each subject receives the exact list in the same order during the second phase. Also, be careful not to tell the subjects what will happen during Phase 2.

Instructions for Phase 1: "This experiment has two phases. In the first phase, you will be asked to learn a list of nonsense syllables. I will show the items, written on notecards, one at a time. After I have shown you all 13 items, I will ask you to recall the items in order. We will continue until you are able to recall all the items in order. Once you have recalled the items correctly, that will be the end of the first phase."

Instructions for Phase 2: "For the second phase, I will ask you to relearn the list of items you originally learned 1 hour ago/1 day ago/1 week ago. We will follow the same procedure. I will show the items, written on notecards, one at a time. After I have shown you all 13 items, I will ask you to recall the items in order. We will continue until you are able to recall all of the items in order. Once you have recalled the items correctly, that will be the end of the experiment."

Scoring and Analysis: For each subject, count the number of trials required to learn the list the first time and the number of trials to relearn the list. To calculate percent savings, subtract the number of trials to relearn the list from the number of trials to learn the list originally. Then divide this value by the number of trials to learn the list originally. For example, if it takes a subject 12 trials originally and 8 trials to relearn, the percent savings is 4/12 or 33%. The *x*-axis should show the delay condition, and the *y*-axis should show the number of lists. The graph should look similar to Figure 1.2, even though savings is plotted in terms of time rather than trials.

Optional Enhancements: Include more delay conditions, increase the number of subjects, and measure the time needed to learn and relearn the lists rather than just the number of trials.

SOURCE: Based on an experiment by Ebbinghaus (1885).

Ebbinghaus (1885) conducted a series of experiments designed to demonstrate the existence of both direct and remote associations. He learned lists of 16 syllables until he reached a certain criterion; in this case, he kept learning until he could repeat the list without error. After a delay, he measured his retention of the lists with the *method of savings*. In this method, a previously learned list is relearned and the difference between the time needed to learn the list to criterion the second time and the time it took to learn it originally represents the savings due to remembering.

Ebbinghaus then constructed "derived" lists, in which item 2 of the original list would be displaced one, two, three, or seven positions. For example, if the original list were I1, I2, I3, . . . , I16, then the derived list, skipping one syllable, would be I1, I3, I5, . . . , I2, I4, . . . , I16. If item I1 can serve as a cue, via a remote association, for item I3 in a derived list with one skipped syllable, and if it can serve as a cue, via a more remote association, for item I4 in a derived list with two skipped syllables, then learning one of these derived lists should take less time than learning a control list. If, on the other hand, there are only direct associations between adjacent items, a derived list will have no advantage over a control list because in both cases the direct association has been severed.

Ebbinghaus found a mean savings of 33.3% in relearning the original list, a 10.8% saving when skipping one syllable, 7.0% when skipping two syllables, 5.8% when skipping three syllables, and 3.3% when skipping seven syllables. In a control condition containing the same syllables but in random order, there was a savings of only 0.5%. According to Ebbinghaus, these findings support the idea of remote associations.

Ebbinghaus is probably best known for the *forgetting function*, the first systematic investigation of forgetting. He first measured the amount of time required to learn (two errorless recitations) a list of 13 nonsense syllables. Then, he waited a specific period of time before relearning the same material and measured how long it took to relearn the lists. He reported the results in terms of percent savings. For example, in 12 tests it took Ebbinghaus an average of 1081 seconds to learn a 13-item list of nonsense syllables. After a delay of 19 minutes, it took him an average of 498 seconds to relearn each list, a difference of 583. The formula (Ebbinghaus, 1885, p. 68) is

$$Q = \frac{100\Delta}{L - 85} \qquad 1.2$$

where Q is the percent savings, L is the time of first learning (including the two errorless recitations), Δ is the difference between L and the second learning (both including the two errorless recitations), and 85 is the time (in seconds) needed to say the two errorless recitations. The reason for subtracting this value is that Ebbinghaus was interested only in the savings of learning. In the example given above, he "saved" 58.5% of the time:

$$Q = \frac{100(1081 - 498)}{1081 - 85} = \frac{58300}{996} = 58.53 \qquad 1.3$$

Although the exact nature of the forgetting function can vary depending on the type of materials, the type of processing, the type of test, and so on, the basic shape appears relatively constant: The largest drop in performance occurs during the period immediately after the test (see Rubin & Wenzel, 1996). As shown in Figure 1.2, Ebbinghaus would have been at 100% at Time 0; waiting only 19 minutes resulted in a substantial drop in performance. By comparison, there is little overall loss from 2 days to 31 days.

Two points should be emphasized here. First, although Ebbinghaus is (rightly) viewed as the preeminent figure in the early study of memory, some scientific research on memory occurred before his book (see, for example, Burnham, 1888; Murray, 1976; Schacter, Eich, & Tulving, 1978). Second, although the majority of his studies can be faulted for using

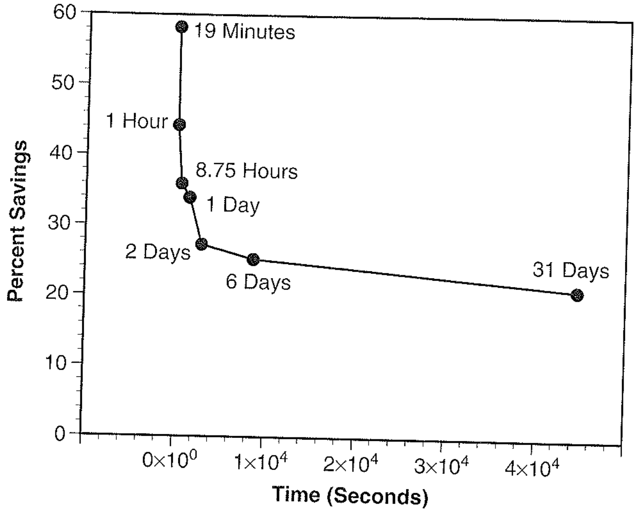

Figure 1.2 Retention of lists of nonsense syllables learned by Ebbinghaus as measured by the method of savings.
SOURCE: Based on data from Ebbinghaus (1885).

only himself as a subject or for using nonsense syllables, all of his important findings replicate and have been at the center of much of the research and theory of the ensuing 100 years (Slamecka, 1985).

Research After Ebbinghaus

Memory research is central to the field of study known as *cognitive psychology*, the area of psychology that studies perception, thought, language, and speech. The field did not really exist until the late 1950s.

In the United States, the two major approaches to research until the 1950s were behaviorism and Gestalt psychology. *Behaviorism*, as propounded by John B. Watson (1913), was both a methodological movement that rejected introspection and a theoretical framework that emphasized the conditioned reflex as the foundation of behavior. Watson took the position that unobservable constructs such as memory, imagery, and consciousness could not be studied rigorously and thus were not appropriate topics for scientific study. Although this did not completely preclude the study of memory, it did severely restrict theoretical development. Behaviorism was gradually replaced with neobehaviorism (e.g., Hull, 1943), the major difference being the acceptance of unobservable mediators between the observable stimulus and the observable response.

Gestalt psychology began in Frankfurt in 1911 with a meeting of Max Wertheimer, Kurt Koffka, and Wolfgang Köhler (Ash, 1995). By 1933 all three held academic positions in the United States, at the New School for Social Research, Smith College, and Swarthmore College, respectively (Murray, 1988). Although most of the experimental research focused on perception, some theories were specifically applied to memory, thinking, and problem solving (see Ash, 1995; Murray, 1995). The Gestalt approach emphasizes the idea of studying the whole (*Gestalt* is German for "whole"); it is often said that this approach can be summarized as asserting that the "whole is different from the sum of its parts."

A large body of research, undertaken outside of both the behaviorist and Gestalt traditions, is usually referred to as *verbal learning*. This approach was a largely atheoretical way of studying the acquisition and retention of verbal material and shared many elements with the functional approach. Many studies from this period will be cited in later chapters, and many of the concepts identified—especially interference—play prominent roles in current theories of memory.

The study of memory, and cognitive psychology in general, underwent a major change between 1940 and 1970. One illustration of how radically things changed over this 30-year period concerns two books, both called *Cognitive Psychology*. Thomas Moore's book, published in 1939, had relatively little impact on research; Ulric Neisser's book, published in 1967, was an instant classic and had a tremendous influence (see Surprenant & Neath, 1997). One major reason for the different reactions to these books was the introduction and acceptance of the concept of information, the basic unit of cognitive processing. The idea, quite simply, is that one can think of information flowing through the cognitive system in a way similar to information flowing through a computer system. Although the original conception of information as put forth in information theory (e.g., Attneave, 1959) is no longer widely accepted, the basic idea still forms the foundation for cognitive psychology.

Chapter Summary and Further Reading

This chapter has provided only the briefest of sketches of the centuries of thought given to memory. Scientific psychology did not begin until Fechner began his research on psychophysics in the 1850s, and the scientific study of memory did not begin until Ebbinghaus began his series of studies a few years later. What distinguishes the work of Ebbinghaus from earlier researchers is that he outlined two possible theories, derived a testable prediction that could distinguish between the two possibilities, and then conducted an experiment. Since Ebbinghaus, two major approaches to the study of memory in the United States were behaviorism and Gestalt psychology, although much research was also done in what is now known as the verbal learning approach. Cognitive psychology began in earnest in the 1960s.

The following sources are recommended for a more complete understanding of the history of experimental psychology in general and of memory research in particular. Every student of memory should read Ebbinghaus (1885), and Slamecka (1985) provides an excellent assessment of Ebbinghaus's contribution. Burnham (1888) provides an historical overview of early memory research, and Murray (1976) discusses research on human memory in the 19th century. Diamond (1974), Herrmann and Chaffin (1988), and Herrnstein and Boring (1965) all provide translations of much of the early work on memory. Yates (1966) offers an excellent history and analysis of mnemonic techniques, particularly in the Middle Ages, and Carruthers (1990) examines memory in the medieval period.

The classic history of experimental psychology is by Boring (1950). Watson (1968) also serves as an excellent starting point, offering biographical, philosophical, and psychological summaries of important figures in the history of psychology and supplying translations and short extracts of original sources. Zusne (1975) offers a biographical sourcebook of people who influenced psychology, and Watson (1915) provides some biographical information on Vives, a figure much overlooked by psychologists.

Murray (1995) examines the contribution of Gestalt psychology to the cognitive revolution, and Gardner (1985) provides a history of cognitive psychology.